Surrogates for Fair-Weather Photovoltaic Module Output

Dominik Falkner[1,2], Michael Bögl[1], and Michael Affenzeller[2,3]

[1] RISC Software GmbH, Hagenberg

[2] Institute for Formal Models and Verification, Johannes Kepler University, Linz

[3] University of Applied Sciences Upper Austria, Hagenberg

dominik.falkner@risc-software.at

Background and Motivation The success of the energy transition and the future stability of energy networks are deeply tied to the output of renewable energy like photovoltaic (PV) modules. International Renewable Energy Agency reports the need for a rapid increase in the deployment of renewables to meet the 1.5 ℃ climate goal, they predict a seven-fold increase by 2030 [1]. The federal association for photovoltaics in Austria, project that PVs produce 15 percent of the total consumption by 2030 [2]. As PVs gain prominence in the energy mix, so does their impact on the power grid's balance, which is especially significant for energy providers. Furthermore, compared to large PV power plants, the increasing number of small, privately owned PV systems has relatively greater installation diversity per kilowatt produced. Therefore, there is a need to create tools that can simulate PV module output across a diverse set of parameters. In this paper, we tackle the issue by investigating the construction of surrogate models for fair-weather PV output and provide a benchmark for their performance as well as a process to build surrogates for PV modules.

Method At present, the PVGIS [3] tool is available for calculating fair-weather PV output. It is an online platform which offers hourly data on solar radiation and photovoltaic system efficiency for locations across Europe, Africa, Asia, and America. It estimates the output based on satellite image analysis, taking into account various installation parameters such as slope, azimuth angle, peak installed power, system loss, and the type of PV technology used. Nevertheless, PVGIS has a rate limit in place. Moreover, as a web-based application, it comes with inherent delays due to network transmission, which makes it unsuitable for larger-scale simulations. In the first step, we aim to build a crawler for PVGIS to amass data for training and evaluating surrogate models. The crawler facilitates downloading and storing data for parametrized modules. The resulting software tool will be made freely available via Github. For the purpose of building surrogates, state of the art models like NHITs [4] and PatchTST [5] are employed. NHITs is based on multilayer perceptrons, and PatchTST represents a transformer-based approach. Both have been shown to be effective in modeling time series and are suitable for the purposes proposed in this study. Moreover,

both support transfer learning, which is used to train from multiple datasets [6]. Additionally symbolic regression, a white-box model, is considered. It has shown proficiency in identifying nonlinear associations and generalizes well [7].

The study investigates the construction of surrogate models for different parameterized PV modules. For data collection, the crawler gathers fair-weather output data from locations sampled from predetermined areas around the world. The initial experiment evaluates the models' capability to accurately estimate the power output of these modules without varying parameters. In the subsequent experiment, parameters are varied for each location. This assesses the possibility of establishing a surrogate for different parameter configurations. The final experiment gauges the models' proficiency to generalize. It involves methodically enlarging the primary sampling region and subsequently testing the models using data from the newly included zones, thereby establishing a standard for accuracy within a specific region. Our research lays the groundwork for the development of surrogate models for PV modules, which offer a good approximation to the PVGIS service. Moreover, surrogates are fast enough to be used in real-time contexts. This study acts as a precursor for future studies which incorporate weather to mirror real-world PV outputs. For this purpose, a detailed description of the methodology and data will be made available.

Acknowledgements The work was done within the project "Secure Prescriptive Analytics", funded by the state of Upper Austria as part of the program "#upperVISION2030".

References

1. International Renewable Energy Agency: World Energy Transitions Outlook 1.5C Pathway 2022 edition. IRENA (2022), ISBN: 978-92-9260-429-5
2. Bundesverband Photovoltaic Austria: Die Österreichische Photovoltaic und Speicherbranche 2022 (visited on 2023-10-23), https://pvaustria.at/wp-content/uploads/2023_Fact_Sheet_PV_Branche.pdf
3. Joint Research Centre: Photovoltaic geographical information system PVGIS (visited on 2023-10-23), http://re.jrc.ec.europa.eu/pvgis
4. Challu, C., Olivares, K.G., Oreshkin, B.N., Garza, F., Mergenthaler-Canseco, M., Dubrawski, A.: N-hits: Neural hierarchical interpolation for time series forecasting (2022). https://doi.org/https://doi.org/10.1609/aaai.v37i6.25854
5. Nie, Y., H. Nguyen, N., Sinthong, P., Kalagnanam, J.: A time series is worth 64 words: Long-term forecasting with transformers. In: International Conference on Learning Representations (2023). https://doi.org/https://doi.org/10.48550/arXiv.2211.14730
6. Oreshkin, B.N., Carpov, D., Chapados, N., Bengio, Y.: Meta-learning framework with applications to zero-shot time-series forecasting (2020). https://doi.org/10.1609/aaai.v35i10.17115
7. Affenzeller, M., Winkler, S.M., Kronberger, G., Kommenda, M., Burlacu, B., Wagner, S.: Gaining deeper insights in symbolic regression. In: Genetic and Evolutionary Computation, pp. 175–190. Springer New York (2014). https://doi.org/10.1007/978-1-4939-0375-7_10, https://doi.org/10.1007/978-1-4939-0375-7_10